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Digital Map Update Using Carrier Phase Handheld GPS

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Abstract

The vast infrastructure development requires a quick and cost-effective tool to update or providing of fresh data to digital data base. The conventional method of positioning is very slow and time-consuming. Certainly a nevv technology such as the Global Positioning System (GPS) will help map makers to perform such mapping task. The main aim of this paper is to utilize the advent of low-cost, carrier phase handheld GPS in map updating using differential techniques. The method investigated used hybrid receivers, processing through the RINEX format. The seamless GPS data are then overlaid using AutoCad software to produce the final output. The significant consequence of the output is that GPS techniques using integrated receivers seems to be cost-effective and adequate for digital mapping and an effective method of data acquisition.

1.0 INTRODUCTION

GPS is an acronym for the Global Positioning System which is a system of satellites implemented by the United States of Department of Defense (US DoD) to provide high accuracy positioning, velocity information and accurate time transfer to suitably equipped users on a global basis. GPS was primarily designed as a navigation system. Instead, the complexity of its emitted signal has widened its application areas. It is not the intention of the author to discuss on the GPS system in this paper but the interested reader can refer to Wells et. al (1986), Scherrer (1985), Leick (1990) and King et. al (1985).

The expectation of the use of GPS as a surveying tool is becoming reality. Applications of GPS positioning technique have been demonstrated in many published articles. Blair (1989) summarized the practical application of GPS in terms of time saving, instrumentation and accuracy. GPS technique has been used by Lambert and Taylor (1989), and McLellan et al (1989) in deformation monitoring. Decimetre positioning of aeroplanes for photogrammetric applications have been described by Kinlyside (1989) and Biggs et al (1989). New opportunities arising from GPS include the integration of GPS techniques with other navigation sensors such as the inertial navigation system. This integrated system has been fully tested in Finland for road mapping (Byman and Koskelo, 1991). Schwarz (1990) on the other hand, described integrated GPS/inertial navigation system in a highway inventory system.

Other than the cited examples, there are many more applications of GPS positioning technique for example in cadastral surveying (Gerdan and Talbot 1990, Gerdan 1991 and Duffy 1991); ground subsidence studies (Chrzanowski et al 1991) and contribution to Geographic Information System (GIS), (Canon 1990; Cross 1991 andAppleby 1991).

This paper aims to amplify the utilization of GPS positioning in digital mapping using carrier phase handheld GPS receiver. The sample data used in the study was electric poles. In addition, discussion includes the integration of different types of receivers with different technologies in order to minimize the cost and to take advantage of the existence of low cost, handheld receivers.

2.0 SURVEYING WITH GPS

The signal transmitted by the GPS satellites can be tracking by different receivers according to their mechanism. The basic GPS observable for surveying applications is carrier phase measurement There are many methods of GPS positioning available for surveying applications which will be briefly discussed in the subsequent section and illustrated in Figure 1 through 4.

2.1 Static Surveying

Static GPS surveying requires one receiver to be stationed at a known point (position) and the other receiver is at the new station. Both receivers should be stationary during observation for a period of time (15-60 minutes). A time span will contribute to redundancy, and hence this technique provides a higher accuracy in positioning. The high accuracy attainable using this technique is due to the techniques referred to as differenced measurements.

2.2 Kinematic Surveying

Static surveying involves two receivers remaining stationary for a period of time during observation. Contrarily, in kinematic surveying, one receiver remains stationary while the other receiver roams from point to point of interest while keeping continuous lock of the satellite signal. Kinematic (or Stop and Go) surveying is an extension of kinematic surveying, which makes use of carrier phase measurement. This technique requires an initialization process in order to determine integer ambiguity. This explains why the rover and fixed receivers must be continuously tracking to at least four satellites whence less occupation time (e.g. one to two minutes) is required to stay on station. Loss of lock requires the rover receiver to return to a previously known point and this is the disadvantage of the technique. In addition, the routes between stations must be relatively clear of obstructions (i.e. clear view to the satellites).

Currently, a new technique has been developed in order to determine integer ambiguity while the rover was moving. The method is known as on-the fly (OTF) GPS surveying. The method requires the accomplishment of the ambiguity resolution while the receiver is in motion (Abidin, 1996). Subcentimetre level accuracy can be achieved using this method compared to a metre level accuracy using pseudo-range differential positioning. This new methods offer a lot of applications in GIS, hydrographic surveying and etc.

2.3 Pseudo-Kinematic Surveying

Pseudo-kinematic (reoccupation or broken static) surveying is different from kinematic surveying due to the fact that it is not necessary to maintain continuous track on satellite while moving from point to point. Hence the receiver can be switched off while moving (Remondi, 1991). It is another type of static surveying technique with the exception that occupation time is lessened (one to five minutes) but requires reoccupation after a period of time (one to two hours). Reoccupation is the main requirement of this technique because the effectiveness of the technique depends primarily on different satellite geometry.

2.4 Rapid-Static Surveying

The three GPS surveying techniques mentioned earlier, are based on single frequency phase data (L1). Nevertheless L1 and L2 phase measurement are available and are normally used in high precision static surveying. The majority of geodetic receivers have L1/L2 carrier phase measurements and therefore, errors, such as atmospheric errors, will be eliminated. The problem with static surveying is that it requires a lengthy period of observation. The development of rapid-static surveying techniques in the last few years holds great promised substantial productivity gains over classical static surveying. The secret of rapid-static surveying is the ability to reliably resolve the initial phase ambiguities with just a few minutes of observations using the method called Fast Ambiguity Resolution Approach (Frei & Eckels, 1992).

2.5 Differential Positioning0

Many writers on GPS refer to the term "differential" for navigation purposes rather than surveying. Differential surveying (or differential correction technique or widely known as Differential GPS or DGPS) involves pseudo-range data and can be implemented either in real-time or post-processed. This method involves one receiver remaining stationary at a station of known coordinates (base station) while one or more receivers are mobilized. The position fix obtained by the base station is compared with the known position and an error vector is produced. If this technique is to be used in real-time, a powerful data link is required to transmit data from the base station to the mobile receivers. The concepts of post-processed differential positioning is the main technique adopted throughout the study.

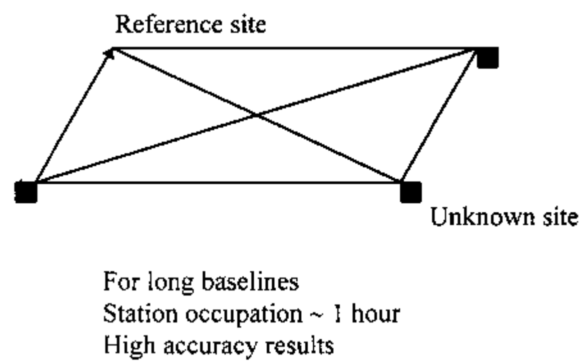


Figure 1. Static Surveying.

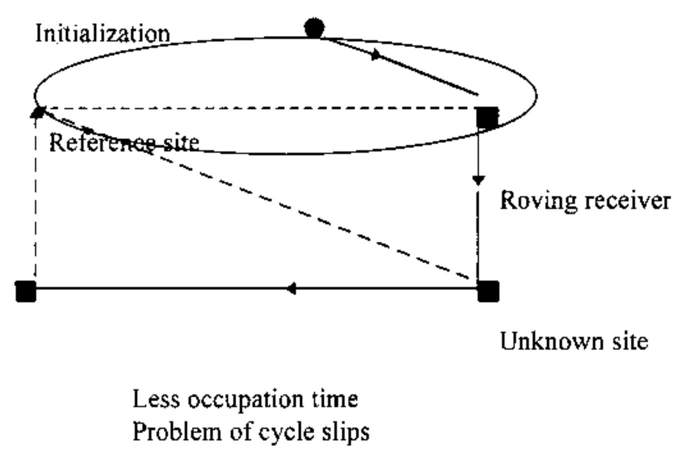
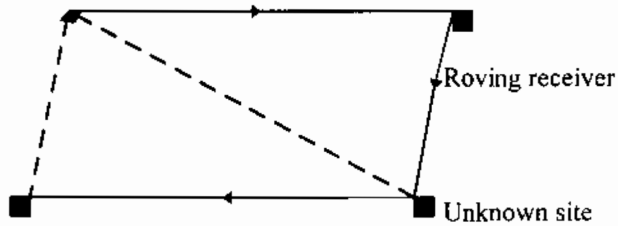
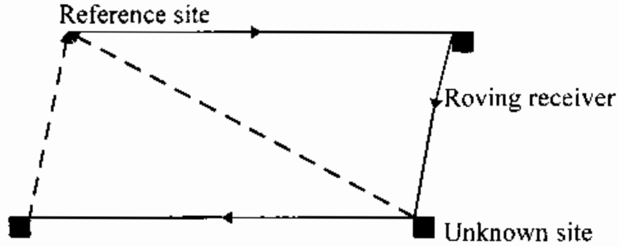


Figure 2. Stop and go surveying.



Occupation time (1-5 minutes)
Reoccupation after one hour
Employed when regular kinematic impractical

Figure 3. Pseudo-kinematics surveying.



Less occupation time
Require dual frequency data
High accuracy results

Figure 4. Rapid static surveying

3.0 METHODOLOGY

3.1 Test Site

The survey site is located in Belmont, Western Australia. The field test was performed along one of the roads which consists of a series of electric poles from the transformer nearby. The location of the survey site was selected for several reasons:-

(i) *Relatively medium distance from the base station (approximately 10 km).*

(ii) *The existence of a digital database of the area. The digital database was supplied by the Topographic Section of Department of Land Administration (DOLA), Western Australia.*

(iii) *To assess the practicality of GPS within a developed locality with many overhead obstructions in the main.*

Figure 5 shows typical overhead obstructions within the survey site which is not suitable for GPS kinematic surveying. A total of 30 poles have been observed during the study. In addition, the survey site also consisted of three SSM (Standard Survey Mark) marks which were used in the study for benchmarking. The SSM marks are coordinated points established by the DOLA of Western Australia. Each point has a position (horizontal and vertical) as well as geoid-spheroid information.

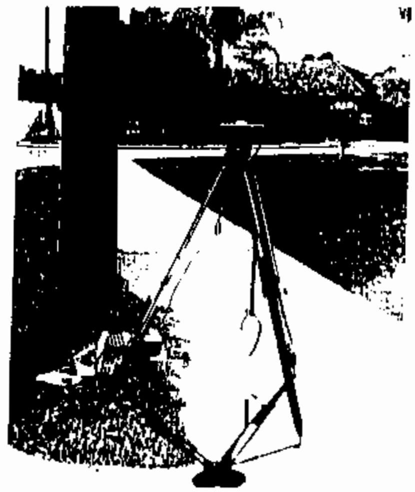


Figure 5. Instrumentation and typical overhead obstructions within test site.

4.0 DATA ACQUISITION

Field data collection can be divided into two stages; (1)The establishment of base station and (2) Data collection to map utility infrastructure (i.e. electric poles).

4.1 Establishment of Base Station

The base station or monitor station as used in relative or differential positioning, is a point with known coordinates. In real DGPS application, the base station will continuously track and decode data from satellites.

For the purpose of the study, the office of John Higham & Associates in Manning, Western Australia has been designated as the base station. One of the air holes on top of the office has been used as a point to position the receiver's antenna. A special plastic pipe has been fitted with a screw which can fix any type of antenna to act as a pole (see Figure 6). The size of the pipe comfortably fits the diameter of an existing air hole pipe. The pole stability is substantial and so thus, supports the weight of the antenna. The supplementary requirement of the pole is that it should be unobstructed to GPS signals.

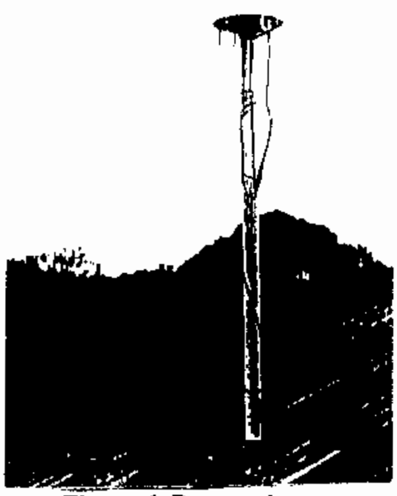


Figure 6. Base station.

The next step in the establishment of the base station was to determine the coordinates of the pole or antenna's phase centre. Geodetic GPS methods were employed to accurately determine the position of the base station relative to the nearest SSM's marks. Two Trimble 4000ST receivers were used. A static surveying technique was adopted as it was the best method to achieve the highest accuracy.

4.2 Spatial Data Collection

The survey was performed using two different types of receivers. The first receiver is a medium cost geodetic receiver (Terrasurv 2000) and the second is a low cost handheld receiver with RINEX capability and acclaimed sub-metre accuracy with carrier-phase observation (Magellan PRO 5000). The Terrasurv 2000 receiver was stationed at the base station and Magellan PRO 5000 receiver act as rover. Figure 5 shows instrumentation used during the study which include Magellan PRO 5000, external antenna and laptop computer near the pole.

Mission planning has been done using Magellan processing software prior to field observations. The geometric quality for submetre accuracy differential carrier phase using Magellan PRO 5000 depends on CPDOP (Carrier Phase Dilution of Precision). The best geometric quality for an observation is when the value of CPDOP is less than 20. The CPDOP used here is different from PDOP but it serves the same purpose as PDOP i.e. geometric figure of merit for Magellan PRO 5000 carrier phase fixes.

The time span used during the survey for each point was 10 minutes. A total of 30 poles were acquired in the prescribed test site. This reflects the obstructions within the site which allow only a few points that are hindrance to GPS signals. The pole itself introduces a problem because it is impossible to setup a receiver adjacent to a pole and hence an offset is necessary. Generally, offset points of about two metres distance from a pole are established thus permitting a receiver to obtain an obstructed signal from GPS. At the test site, as well as recording the data from several poles, 10 minutes observation was also performed on three SSM's mark.

5.0 DATA PROCESSING

The data post-processing involves two stages. The first stage of processing converts the Terrasurv 2000 observation file into RINEX observation file format using TOPAS (Terrestial and Orbital Positioning Adjustment Software) software. To determine the position of measured points, carrier phase differential must be implemented. Carrier phase differential uses essentially the same error correction method as pseudorange differential. The difference is the type of data being used to compute the correction. In carrier phase differential, all position fix information is derived from carrier phase data. The known location of the base station allows the computation of a carrier phase differential between measured position and known position. The second stage involves a differential correction using Magellan processing software. The software uses the ephemeris file created from Magellan PRO 5000, the base station observation file (in RINEX format) and the rover's observation file (no need to be converted into RINEX format).

Several parameters need to be defined before differential processing is executed. First, known position of the base station is needed to solve for differential correction. The second parameter is the observation and ephemeris files created during measurement. After the set-up and differential commands have been thoroughly filled, differential processing can be executed. A detailed description on the differential processing can be found in Zulkarnaini (1992).

6.0 GPS MAPPING

As mentioned earlier in Sec. 3.1, digital data was provided by the DOLA of Western Australia. It was captured using the Microstation/Intergraph acquisition system. Generally it consists of 63 levels in layers of which some are spares. For the purpose of the study, only a few layers e.g. roads and access ways, power/communication and associated features, contours etc. are of interest.

In order to take advantage of the availability and simplicity of the AutoCad software, the Microstation design files (DGN) have been converted into DXF format files. In addition, the new data file (or layer) has been created from GPS data obtained from Sec. 5.0. This allows seamless GPS data to be overlaid on the existing data files. The final map display consist of different map attributes including newly mapped GPS data.

7.0 ANALYSIS OF RESULT

An analysis was made on three SSM marks observed during the study because it best represent the overall accuracy achieved. Nevertheless, an extracted portion of map display in Appendix 1 illustrates the discrepancies between the existing poles and GPS observed poles plotted at a scale of 1:2000. This can be identified by observing the two coincidence circle (hardly recognizable) which represent the existing and GPS observed poles. The symbol for these features have been exaggerated in order to highlight the difference. Table 1 gives the GPS measured coordinates and the known coordinates of the three SSM marks. The coordinates system are in AMG (Australian Map Grid) coordinate system. During the study, only the horizontal coordinates were considered. Table 2 shows the difference between the observed and known coordinates together with their linear and baseline errors.

The level of accuracy obtained from the study has verified the practical application of low-cost handheld carrier phase GPS receiver in digital mapping.

	GPS Position		Known Position	
Station	**Easting (m)**	**Northing (m)**	**Easting (m)**	**Northing (m)**
SSM 1	398836.565	6465130.527	398836.393	6465130.436
SSM 2	399153.070	6464065.611	399152.937	6464065.527
SSM 3	399664.530	6464315.300	399664.010	6464315.429

Table 1. GPS observed and known coordinates of control points.

	Coordinate Difference		Error	
Station	**Easting (cm)**	**Northing (cm)**	**Linear (cm)**	**Baseline**
SSM 1	17.2	9.1	19.4	1:50,000
SSM 2	13.3	8.4	15.7	1:58,000
SSM 3	52	-12.9	53.5	1:18,00

Table 2. Coordinate differences and errors.

8.0 CONCLUSION

In conclusion, the study has identified a substantial goal of achievement and will create opportunities and impetus for the implementation of GPS mapping and map update to wide variety of organisation or group. The study has demonstrated that the existence of carrier phase handheld GPS receiver with medium level of accuracy can provide seamless data into existing digital data bases for updating or the provision of fresh data.

The accuracy standard for any plotted map relates to map scale. Scale determines the smallest area that can be drawn and recognized . If the minimum discernible mark on a map assuming a minimum spot of 0.5 mm, the planimetric accuracy corresponds to approximately one metre on the ground for a 1: 2000 map. The accuracy achieved (see Table 2) provide evidence that GPS can facilitate mapping activity and conform to accuracy standard.

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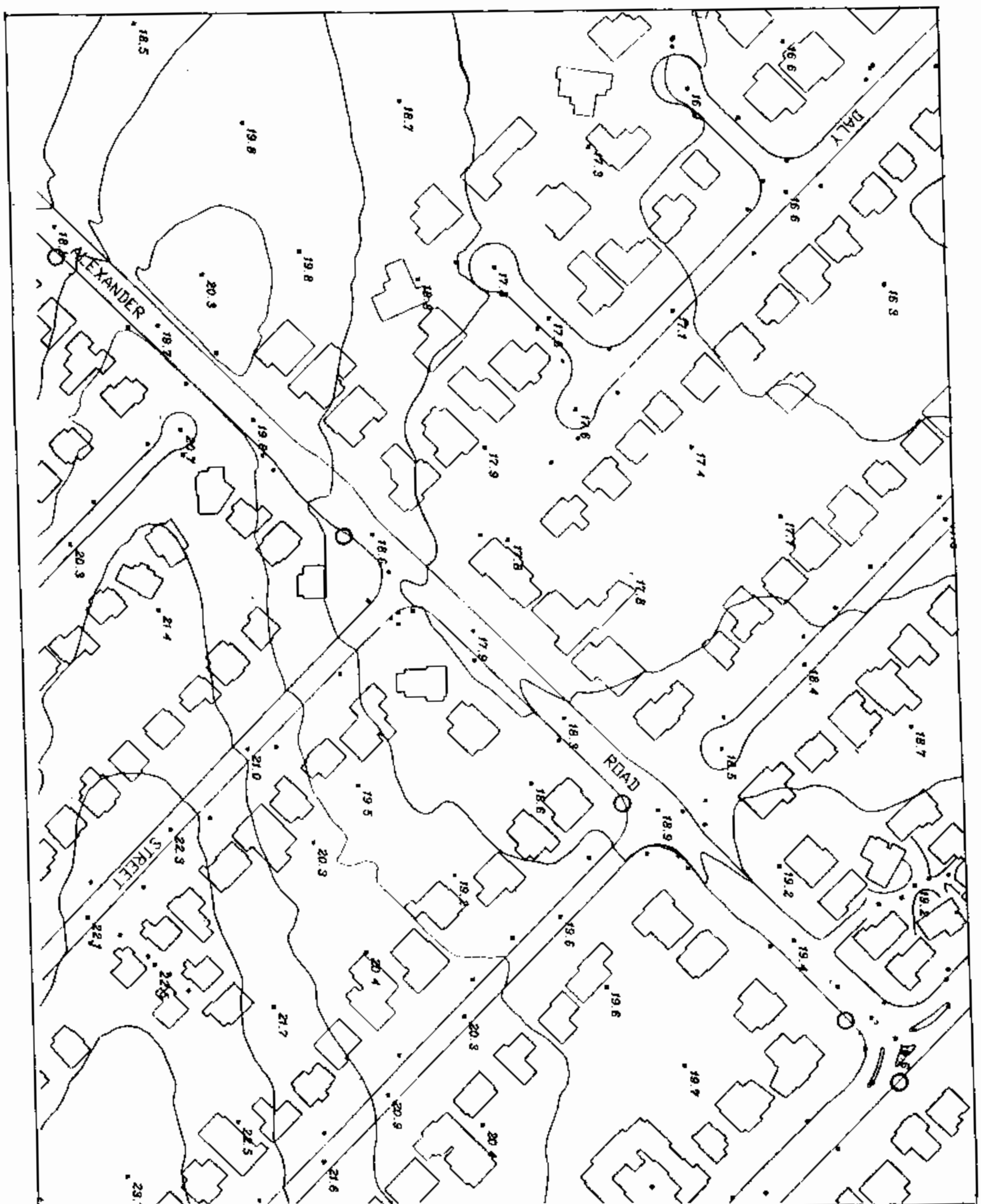
Appendix 1: An Extracted Portion of Map Display Showing Existing and GPS Observed Poles.



LEGEND

O SELECTED EXISTING POLE

O GPS MEASURED POLE